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THE STEADY-STATE SIMULINK MODEL OF THREE-PHASE ASYNCHRONOUS MOTOR USED ONBOARD A SHIP

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Abstract: *A ship plant consisting in a three-phase AC asynchronous motor is well known onboard a ship. The steady-state numerical model helps to study the transitory phenomena's regarding power supply network.*

Keywords*: asynchronous motor; numerical model*

1. Introduction

The three phase asynchronous motor also known as induction machine is a device that is used in almost all electrical applications. This is the reason for such device to be used in naval domain.

The study that is described in the article is based on a 160 Kw three-phase asynchronous motor mathematical model which is implemented in Matlab Simulink. The Asynchronous Machine block implements a three-phase asynchronous machine (wound rotor, single squirrel-cage, or double squirrel-cage). It operates in either generator or motor mode. The state space model is based by the mode of operation that is dictated by the sign of the mechanical torque:

- If torque is positive, the electrical machine is a motor;
- If torque is negative, the electrical machine is a generator.

The mathematical model consists in two types of machines:

- Electrical System of the Wound-Rotor or Squirrel-Cage Machine;
- Electrical System of the Double Squirrel-Cage Machine.

For the study described in the article the wound-rotor system is used. The electrical scheme is presented in fig. 1.

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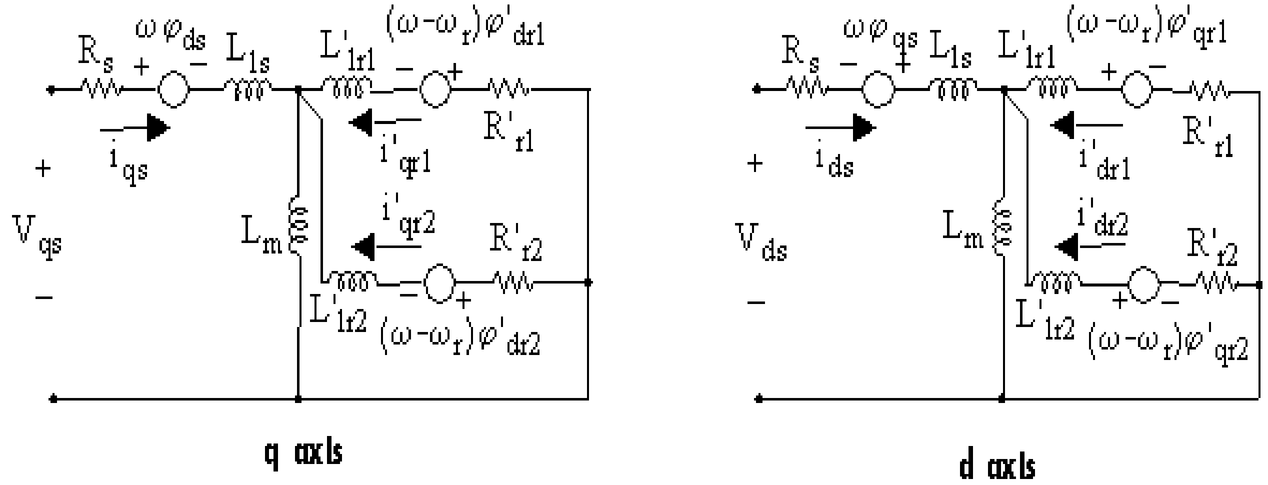

Figure 1

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$$V_{qs} = R_s i_{qs} + d\varphi_{qs}/dt + \omega\varphi_{ds}$$
$$V_{ds} = R_s i_{ds} + d\varphi_{ds}/dt - \omega\varphi_{qs}$$
$$V'_{qr} = R'_r i'_{qr} + d\varphi'_{qr}/dt + (\omega - \omega_r)\varphi'_{dr} \quad (1)$$
$$V'_{dr} = R'_r i'_{dr} + d\varphi'_{dr}/dt - (\omega - \omega_r)\varphi'_{qr}$$
$$T_e = 1.5p(\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds})$$
$$V_{qs} = R_s i_{qs} + d\varphi_{qs}/dt + \omega\varphi_{ds}$$
$$V_{ds} = R_s i_{ds} + d\varphi_{ds}/dt - \omega\varphi_{qs}$$
$$0 = R'_{r1} i'_{qr1} + d\varphi'_{qr1}/dt + (\omega - \omega_r)\varphi'_{dr1} \quad (2)$$
$$0 = R'_{r1} i'_{dr1} + d\varphi'_{dr1}/dt - (\omega - \omega_r)\varphi'_{qr1}$$
$$0 = R'_{r2} i'_{qr2} + d\varphi'_{qr2}/dt + (\omega - \omega_r)\varphi'_{dr2}$$
$$0 = R'_{r2} i'_{dr2} + d\varphi'_{dr2}/dt - (\omega - \omega_r)\varphi'_{qr2}$$
$$T_e = 1.5p(\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds})$$

Equations 1 refers to q axis and equations 2 refers to d axis. The electrical part of the machine is represented by a fourth-order state-space model, and the mechanical part by a second-order system. All electrical variables and parameters are referred to the stator, indicated by the prime signs in the following machine equations. All stator and rotor quantities are in the arbitrary two-axis reference frame (dq frame). The subscripts used are defined in this table 1.

Table 1

Subscript	Definition
d	d axis quantity
q	q axis quantity
r	Rotor quantity (wound-rotor or single-cage)
r1	Cage 1 rotor quantity (double-cage)
r2	Cage 2 rotor quantity (double-cage)
s	Stator quantity
l	Leakage inductance
m	Magnetizing inductance

Table 2

Parameters common to all models	Definition
R_s, L_{ls}	Stator resistance and leakage inductance
L_m	Magnetizing inductance
L_s	Total stator inductance
V_{qs}, i_{qs}	q axis stator voltage and current
V_{ds}, i_{ds}	d axis stator voltage and current
ϕ_{qs}, ϕ_{ds}	Stator q and d axis fluxes
ω_m	Angular velocity of the rotor
Θ_m	Rotor angular position
p	Number of pole pairs
ω_r	Electrical angular velocity ($\omega_m \times p$)
Θ_r	Electrical rotor angular position ($\Theta_m \times p$)
T_e	Electromagnetic torque
T_m	Shaft mechanical torque
J	Combined rotor and load inertia coefficient. Set to infinite to simulate locked rotor.
H	Combined rotor and load inertia constant. Set to infinite to simulate locked rotor.
F	Combined rotor and load viscous friction coefficient

Table 3

Parameters specific to single-cage or wound rotor	Definition
L'_r	Total rotor inductance
R'_r, L'_{lr}	Rotor resistance and leakage inductance
V'_{qr}, i'_{qr}	q axis rotor voltage and current
V'_{dr}, i'_{dr}	d axis rotor voltage and current
ϕ'_{qr}, ϕ'_{dr}	Rotor q and d axis fluxes

2. Mathematical model description

The performances of the three-phase asynchronous motor that is used onboard of the 8200 tdw cargo ship will be presented starting from this point. The main characteristics for the electrical machine are:

- Voltage: 400 V AC;
- Frequency: 50Hz;
- Rated power: 160 Kw;
- 1500 RPM;
- Stator resistance: 0.01379 ohm;
- Rotor resistance: 0.007728 ohm;
- Stator inductance: 0.000152 H;
- Rotor inductance: 0.000152 H;
- Mutual inductance: 0.00769 H;
- Inertia: 2.9 J;
- Pole number: 2.

3. The Simulink model description

The model that is implemented in matlab Simulink is presented in figure 2 and 3.

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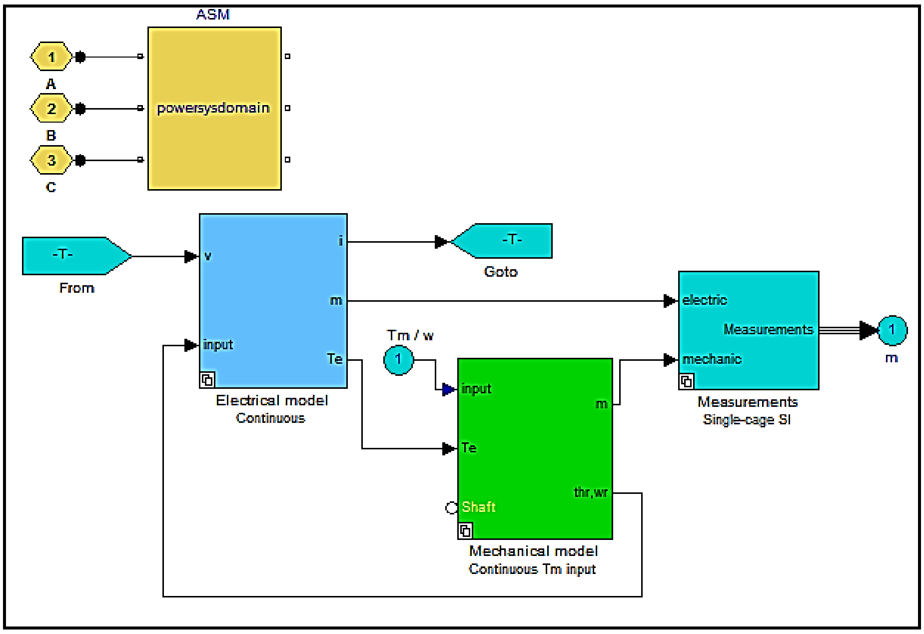

Figure 2

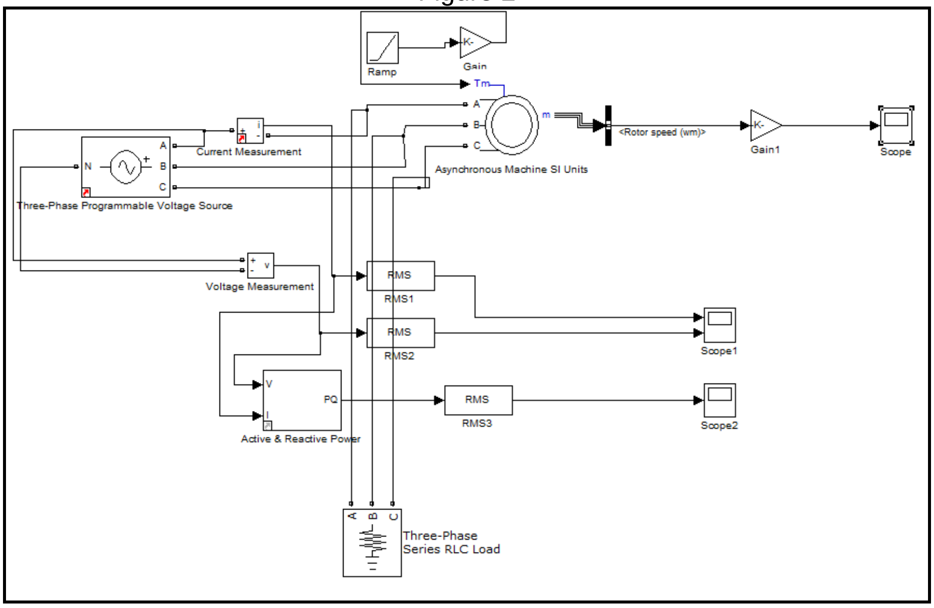

Figure 3

The simulation results are presented in the next graphics.
Current and voltage values:

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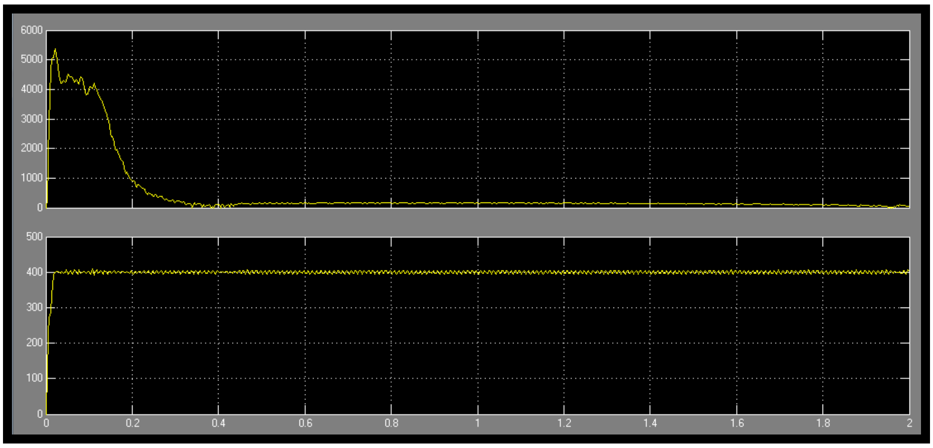

Figure 4

Active and reactive power values:

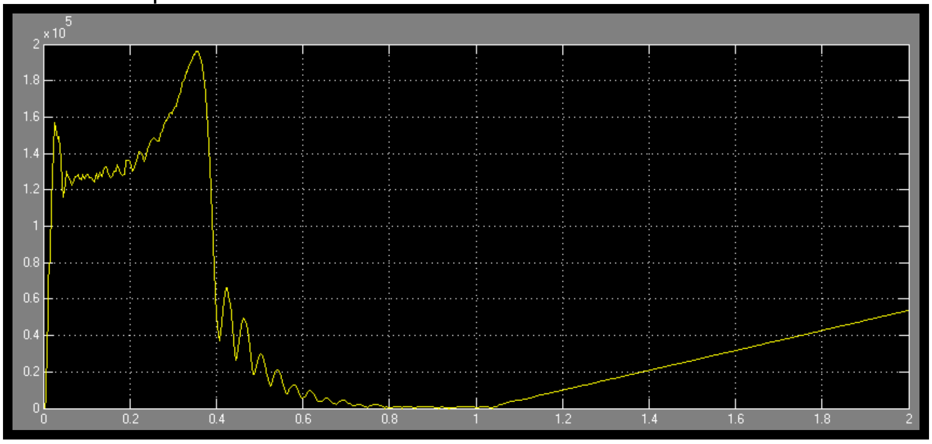

Figure 5

CONCLUSION

The mathematical model consists from two parts: electrical model and mechanical model. Both model are simulated in the Matlab Simulink .

The results presented in these two graphs shows that the 160 Kw three-phase asynchronous motor is well fitted for naval purposes. The time response is minimum so transitory phenomena’s could not affect the equipment’s during period of functioning.

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